The Institute of Physics

BULLETIN

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Professor A. O. Rankine

AN APPRECIATION

It is fitting on the sad occasion of the death of Professor A. O. Rankine, at the age of 74, to recall his unstinting and ungrudging services to the Institute between 1923 and 1936. In a tribute to him written at the end of his six years' service as Honorary Secretary of the Institute, his friend, Professor Allan Ferguson, wrote : "We have learned to regard Professor Rankine as an integral part of the Institute ; it is not easy to envisage a meeting of the Board shorn of his quietly genial presence, and wise counsel, guiding without seeming to direct. It has been an inspiration to more than one to see him, unhasting, unresting, proceed from the completion of one appointed task to the next ; and some who, in Carlylean fashion, are wont to call down fire from Heaven on occasions of very minor stress, have watched, not without a measure of envy, the imperturbability with which Professor Rankine has faced the most serious issues."

Within three months of his election to office, the Institute had acquired its first home of its own—a small suite of rooms in South Kensington, which are now occupied by The Physical Society. It was Professor Rankine who was mainly responsible for bringing to fruition part of the original 1918 scheme for closer collaboration of the societies concerned with physics, through the Institute and the Physical and Optical Societies (which later, under his guidance, amalgamated).

Older members will find it hard to realize that they can no longer turn to "A.O.R."

for that wise counsel and guidance from which so many members benefited. In mourning the passing of yet another distinguished Founder Fellow, it is appropriate to remind ourselves that in founding our Institute thirty-eight years ago " for the elevation of the profession of physicist and the advancement and diffusion of a knowledge of Physics " these men expected to get nothing out of their contributions to this work for themselves but were happy to give of their time and money for the benefit of those British physicists who were to follow them.

H. R. LANG.

Notices to Members

Conference on the Physics of Nuclear Reactors

The Institute's London Conference on " The Physics of Nuclear Reactors " (to be held in conjunction with the British Nuclear Energy Conference) will take place from July 3-6 next in the Institution of Electrical Engineers' building, by kind permission of the Council.

The purpose of the Conference is to keep members of the Institute and its sister institutions abreast of scientific developments in nuclear reactors and to call their attention to the problems needing solution. The Conference is particularly intended for industrial and government physicists, working or likely to work directly or indirectly with reactors, and for lecturers and teachers.

The programme (which is subject to minor modification) is as follows :—

TUESDAY, JULY 3, 1956

Session 1

3.00 p.m.
The President (Sir John Cockcroft) to open the Conference and deliver an address on " Scientific problems in the generation of nuclear power."

4.00 p.m.
Tea. Exhibits of models of reactors, instruments, etc., will be on view.

Evening

7.45-10.00 p.m.
Reception for members of the Conference during which films illustrating reactors and experiments with them will be shown and exhibits will be on view.

WEDNESDAY, JULY 4, 1956

Session 2

10.00 a.m.-12.30 p.m. (with coffee break).
Lecture by Dr. J. R. Dietrich (*Argonne National Laboratory, U.S.A.*) on " The physics of advanced reactors," followed by discussion.

2.30 p.m. *Session* 3
Lecture by Mr. P. W. Mummery (*Atomic Energy Research Establishment, Harwell*) on " Experimental reactor physics," followed by discussion.

4.30 p.m. Tea.

8.00 p.m. *Session* 4
Discourse on " Recent developments in nuclear theory " by Professor R. E. Peierls (*University of Birmingham*).

THURSDAY, JULY 5, 1956

Session 5

10.00 a.m.-12.30 p.m. (with coffee break)
Lecture by Dr. A. H. Cottrell (*Atomic Energy Research Establishment, Harwell*) on " The effects of irradiation on the physical properties of solids and its contribution to the physics of the solid state," followed by discussion.

Session 6

" ANCILLARY PROBLEMS OF REACTORS "

2.30 p.m.
Opening papers : Dr. G. C. Laurence (*Atomic Energy of Canada Ltd., Chalk River*) on " Shielding." Dr. A. Salmon (*Associated Electrical Industries Ltd., Research Laboratory*) on " Control methods." Mr. W. MacRae (*C. A. Parsons & Co. Ltd.*) on " Instrumentation."

4.30 p.m Tea

8.00-8.45 p.m. *Session 7*

Lecture on " The role of chemistry in a nuclear energy project " by Dr R. Spence (*Atomic Energy Research Establishment, Harwell*).

8.45-9.30 p.m.

Lecture on " The role of metallurgy in a nuclear energy project " by Mr. R. L. Rotherham (*Industrial Group Headquarters, U.K. Atomic Energy Authority*).

FRIDAY, JULY 6, 1956

Session 8

" RESEARCH REACTORS AND THEIR USES "

10.00 a.m.-12.30 p.m. (with coffee break)

Opening papers : Dr. W. B. Lewis (*Atomic Energy of Canada Ltd., Chalk River*) on " The Canadian research reactors and their uses." Mr. F. W. Fenning (*Atomic Energy Research Establishment, Harwell*) on " The U.K. research reactors and their uses," followed by discussion.

12.30 p.m.

Concluding remarks by the President.

As far as accommodation permits, members of all grades of the Institute will each be entitled to one non-transferable ticket admitting to all sessions ; tickets will be issued in order of receipt of applications (allowance being made for delays due to overseas postage). In addition, allotments of tickets are being made (for free issue only to their members) to the other four institutions that constitute the permanent British Nuclear Energy Conference and to the Physical Society. No charge is being made for these tickets. A few tickets will be issued to non-members from countries operating or about to operate reactors. If accommodation is available, which is unlikely, other non-members may be enrolled ; non-members will be charged a fee of £2 2s. A charge of 15s. will be made to those wishing to attend the reception on July 3 and an inclusive charge of 7s. 6d. payable in advance is being made to cover the cost of light refreshments to be provided during the Conference.

Applications for admission and other tickets should be made by members as soon as possible on the form enclosed with this *Bulletin*.

A Conference handbook giving full details, including abstracts of the papers and lectures, will be issued early in June together with the various tickets.

The proceedings of the Conference will be published as a supplement to the *British Journal of Applied Physics*.

Recognition of Technical College Diplomas

It was announced in the June *Bulletin* that the Board had agreed to recognize the diplomas awarded by three of the larger technical colleges (Acton Technical College, Birmingham College of Technology and Northampton Polytechnic, London) to students satisfactorily completing " sandwich " courses in physics. These awards will be held to satisfy completely the Institute's academic requirements for Graduateship and corporate membership. Recognition has now been given to two further awards, namely diplomas of Brighton Technical College and The Polytechnic, Regent Street. The courses at these two colleges will be full time courses, not " sandwich " courses. The whole responsibility for the course and examinations in all five courses will lie with the colleges. The only conditions that have been imposed by the Institute is that external examiners shall be appointed with powers and functions similar to those of university external examiners, and that the choice of these examiners shall be subject to the approval of the Institute. In the opinion of the Board it is important that selected technical colleges should be given academic autonomy in order that the standard of their work and the reputation of their awards may be enhanced.

Conference on Graduate Studies in Applied Physics

The Board has accepted an invitation from the London and Home Counties Regional Advisory Council for Higher Technological Education to hold a conference on " Graduate Studies in Applied Physics " jointly with the Advisory Council. The proposal was first made by the Council's Applied Physics Advisory Committee, on

which the Institute is represented, which has given detailed consideration over the past three years to proposals for courses of graduate standard in applied physics that may be offered by universities or technical colleges. The conference will take place in 1956, in London, and will probably extend over two days. Invitations to attend will be sent to representatives of the higher management of industrial firms, professors and other senior academic staff of the University of London and other people associated with the work of the Regional Advisory Council. All members of The Institute of Physics will be eligible to attend.

Detailed arrangements for the conference are in the hands of a small joint committee. The Institute has appointed four Fellows to serve as its representatives, Dr. W. H. Taylor, Dr. J. Topping, Mr. A. T. Pickles and Professor J. G. Wilson ; the Advisory Council's representatives are Professor J. Greig and three Fellows of the Institute, Dr. H. Lowery, Mr. F. Y. Poynton and Mr. N. Clarke. The programme and other details will be announced in the *Bulletin* later.

British Nuclear Energy Conference

Members of the Institute are invited to attend the following meetings arranged in conjunction with the British Nuclear Energy Conference, of which the Institute is one of the five participating bodies.

On March 20, at the Royal Institution at 5.30 p.m., a meeting has been arranged by the Institution of Chemical Engineers and a paper on " The Application of Fluidization Techniques to Nuclear Reactors" will be read. Pre-prints are available from the Secretary of the Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1 ; a stamped addressed label should be sent.

On March 28 at the Institution of Mechanical Engineers, a symposium on Nuclear Energy has been arranged by that Institution. The meeting begins at 3 p.m. and there will be papers on " Nuclear reactors for power generation," " Steam cycles and nuclear power plant," " Heat removal from nuclear power reactors " and " Shielding against nuclear radiation." Accommodation is limited ; applications for tickets should be made to the Secretary of the Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W.1, mentioning membership of the Institute.

Presentation of Projector

The Board records with gratitude the gift to the Institute of a 16 mm. sound-film projector by the Research Laboratory of the British Thomson-Houston Co. Ltd., Rugby. This generous gesture will greatly benefit the Institute's London and Home Counties Branch and the specialized Groups. The formal presentation of the projector was made by Mr. L. J. Davies, Director of Research of the Company, prior to the meeting of the London and Home Counties Branch on January 11. Mr. Davies said that this example of the work of scientists, engineers and skilled craftsmen was given as an expression of appreciation of the work of the Institute and particularly of its value to industry. Dr. J. S. Forrest, Chairman of the Branch, received the gift on behalf of the Board.

International Congress of Radiology

In order to become a member of the International Congress of Radiology which is to be held in Mexico in July next it is necessary to be either a member of a national radiological body, or sponsored by such a body.

The British Institute of Radiology is willing to act as sponsor for any members of The Institute of Physics who wish to attend. Members who are interested should notify the Secretary of The Institute of Physics.

Graduateship Examination

The Institute's Graduateship examination will be held from June 11 to June 15 inclusive in London (The Institute's House), Birmingham (College of Technology), Salford (Royal Technical College) and Paisley (Technical College).

Professor H. Lipson (*Fellow*) of the Manchester College of Science and Technology has been appointed an examiner in place of Professor F. A. Vick who has retired after serving for four years.

Vol. 7, February, 1956

Experimental Methods in Physics for University Students*

By H. J. J. BRADDICK, B.A., Ph.D.

(*Reader in Physics, University of Manchester*)

WE CANNOT discuss the teaching of experimental physics without some consideration of the aim of a university physics course. The course has to meet the needs of some who require a scientific education but whose future will not lie in the physical laboratory as well as those of a majority who will become professional physicists. An undergraduate of the former class may leave active physics at the end of his university course—he needs to be able to appreciate physics rather than perform it, and his main concern with experimentation is to get a good idea of its general methods, its difficulties and its time scales.

The professional physicist has by no means completed his training when he takes his first degree. Whether he goes to a higher degree or not, he will for some years work under more or less close direction, and his choice of lines of work will be guided. His most urgent need is a thorough acquaintance with the tools of his trade, the experimental and theoretical techniques which he will choose, use, and develop throughout his working life.

However, the professional physicist needs to view his work against the background of contemporary physics even at the outset, and the non-professional must acquire some sophistication of technique if his knowledge of physics is not to be entirely second-hand and to some extent nebulous.

The greatest difficulties in planning a course arise from the headlong growth of the body of physical knowledge, always increasing at an increasing rate. Each generation of students is in present practice lectured to and examined upon topics undiscovered when its teachers were undergraduates : the bright student with an eye upon research and the less bright student with an eye upon the examination, the lecturer engaged in original work, are all drawn to the latest facts, theories and speculations, and indeed these must find an important place if we are to present physics as a live, growing organism. The new advance eventually becomes assimilated in the body of " teachable " physics—the subjects which are so familiar to the teachers that they can be presented in a well-thought-out way, and something else becomes the new and attractive subject. There is a real and inevitable tendency to reduce the time and emphasis laid on what is rather unsatisfactorily called " classical physics."

The difficulty is sometimes aggravated by unduly traditional teaching of classical physics, in schools and in elementary university classes. Some schools at any rate leave their students to believe that the tangent galvanometer and the moving coil galvanometer are equally important instruments, and relatively few undergraduates realize that active research is going on in such fields as friction or electromagnetism.

My experience is that a moderate student with a certain acquaintance with meson forces often finds it difficult to answer an oral question—how would you measure a current of about one thousand amperes.

Such knowledge and, much more important, the ability to think about such problems, is however essential to the beginner in

* A lecture given to the Education Group on November 22, 1955

research or in an industrial laboratory, and in my opinion, it can with advantage form a definite part of university physics teaching.

The need is not entirely met by laboratory work, since it is difficult, within the limits of time and material resources, for a teacher to guide and help students in the laboratory without planning the experiments in some detail. The policy we have evolved in the third year teaching at Manchester has at present as its main features :

(1) Laboratory experiments are fixed in the sense that apparatus has been acquired or designed for them, and that a definite exercise or measurement is initially prescribed. No detailed instructions are given, but a card index of references to books and papers is maintained. Students are encouraged to add to this any references which they may unearth. Many of the experiments are difficult in the sense that the demonstrators cannot diagnose faults in an infallible way, but can only make suggestions to the students about the next step to be taken.

Both the demonstrators and the students can and do make suggestions about modifications to apparatus, extension, curtailment or modification of the aims of the experiment. As an example we have a regular experiment on thermal noise measured in an amplifier with various values of input resistor. Several students have wished to measure the effect of the temperature of the resistor on the noise, and have modified the apparatus to allow this to be done. Most students do four or five experiments during the year.

(2) At the end of an experiment, the pair of students concerned is invited to an interview with two members of the staff. The interview is a serious matter, usually lasting half an hour or more. It is often in form an oral examination on the conduct and theoretical background of the experiment, and a critical discussion of the results obtained. It differs from an examination in that missing answers are supplied on the spot or by recommending reference to books and papers. It is valuable to the staff in assessing candidates' abilities—I keep such brief notes as help when graduates apply for references and testimonials. The interviews invariably begin with a request to the student to state briefly what he has been doing, and one may hope that the lesson will help the young industrial physicist in his occasional task of explaining his work to ignorant and highly placed persons. It was my wartime experience that Junior Scientific Officers usually began explanations to Air Vice Marshals with "Well, Sir, you see this little knob down here—it allows us to apply a correction for . . ." One may even dare to hope that an oral summary helps the student himself to see the experiment as a whole after his long pre-occupation with detail.

(3) We have introduced what we call Design Studies in which a student is set an experimental problem, and is required to design and specify the apparatus and procedure for solving it. He may consult with demonstrators, and his solution is criticized at a final interview, but the experiment is not, in general, actually carried out.

In a fully-developed example, a student might have to make an initial calculation to see if the proposed experiment were feasible, or offered any advantages over well-known methods of finding the same result. He might then have to sketch important mechanical parts of his apparatus (though not to draw them in the engineering sense), to choose electrical circuits and specify values and ratings of components. His work might involve an optical system and he would have to specify the focal lengths and general characteristics of lenses. This is of course what has to be done by anybody planning a physical experiment for measurement or research—it involves marshalling knowledge of a number of branches of physics and testing and developing mental activities which are not tested by orthodox examinations nor developed in preparing for them. It is an obvious weakness of many students that they feel they cannot rely on developing from their knowledge the answers to even elementary problems—they feel safe when they can acquire certain packets of remembered information which can be released when triggered by a more or less relevant examination question. I hope that the system of design studies is a possible corrective. It

allows the students' ideas a larger range than do practical class experiments ; it involves references to books and periodicals and specially it involves practising the calculation of orders of magnitude which must become a daily habit of the working physicist. The system has only been in use for a year, it involves no difficulties of administration and, as far as one can judge, it is a valuable method of teaching.

(4) I have for a number of years given a lecture course on the Physics of Experimental Method and eventually I wrote a textbook which was a considered version of the course, rather expanded with factual matter to give it some value as a reference book. The course deals with a kind of applied physics—physics applied to laboratory experiment, but it is aimed less at describing the contemporary state of particular techniques than at emphasizing those principles of physics which are specially valuable in giving rise to techniques and demonstrating those simple sorts of calculation which arise when an experiment is first planned. The descriptions of particular devices and experiments then fall into place as illustrations.

A course like this can hardly be exhaustive, and some topics are chosen because of local interest—I now comment on some of the choices made.

Some account of methods of systematic computation and the layout of numerical work is obviously useful. Attention is directed to the use of slide rules and calculating machines—a small hand calculating machine is available in the laboratory and is regularly used for any experiment which involves accurate computation. Elementary applications of least squares are also taught and applied in the laboratory. It is my experience that many students attribute too much significance to the analysis of errors by the classical procedure—it is something which can be memorized and on which questions can be set, and random errors are therefore unconsciously exalted above the systematic errors which require thought (and, to be fair, experience) for their appreciation. It is therefore important to stress systematic errors both in lecturing and in discussing laboratory work.

The mechanical design of apparatus next claims attention—unfortunately only a few general ideas, such as the principles and limitations of kinematic design, can be treated systematically, and I find it necessary to have some *ad hoc* teaching of selected elementary points of design. The same sort of difficulties arise in discussing the properties of constructional materials—some account is needed to supplement the usual courses on properties of matter, special attention is called to a few materials which have outstanding or peculiar properties. In particular the discussion of the effect of temperature on glass provides a scientific basis for glassblowing procedures. Vacuum technique is then treated, with some special attention to the properties of low pressure flow, the principles of pumps, and the phenomena which may be used for measuring low pressure.

Electric and magnetic measurements can largely be covered by reference to the standard textbooks, but there are certain topics, for example the use of four-terminal resistances, the properties and uses of moving coil galvanometers, which are usually underexplained from the point of view of the laboratory worker. It is also possible to illuminate some points of real difficulty, for example the effect of the Wagner earth in alternating current bridges. For practical and historical reasons the use of valves in electric circuits is often taught separately from general electrical circuit theory, and the experimental methods course provides an opportunity of uniting the subjects. The main things in electronics which we stress are rough calculations of such quantities as the frequency limitations of amplifiers ; very bold approximations are justified if the components have 20% tolerances. The principle of feedback is treated—it is desirable in such a course to point out that it is a principle of very wide application, and to describe simple servo systems as illustrations of its use outside the purely electrical sphere.

We then teach certain topics in optics which lie on the fringe of conventional courses

—the aberration characteristics of optical systems such as camera lenses, telescope and microscope objectives considered from the point of view of a man who wishes to use such systems rather than to design them, the eye, the photographic plate and other radiation detectors.

Several lectures are then devoted to those fluctuation phenomena which set limits to physical measurement. It happens that the laboratory is associated with several researches in which the measurements are limited by noise, and the subject is important in any experimental work which involves wide band amplification.

Finally we discuss the techniques of particle detection in nuclear physics—a subject interesting in its own right as well as one of increasing practical importance. The lectures on this subject provide admirable illustration of the principles of electronic circuit design, and amplification of the more " classical " parts of a nuclear physics course —that is to say the properties of fast moving particles.

I think that a course of this kind has two useful effects—it gives students a number of approximate quantitative ideas which link more abstract teaching with laboratory practice, and it bridges the gaps between the subjects into which our subject is divided by tradition and administrative convenience.

APPENDIX I
THIRD YEAR LABORATORY
1955—56

1. *Thermal conductivity.*

Determine heat conductivity of a (rock) specimen by inserting a disc in a brass bar and comparing temperature gradients. Cf. Bullard & Benfield, *Proc. Roy. Soc.*, **173**, 1939.

2. *Timing pendulum.*

Compare swings of pendulum with an oscillograph time base controlled by quartz crystal. Investigate the variation of period with amplitude.

3. *Resistor noise.*

Measure R.M.S. amplitude of thermal noise using an amplifier with measured frequency characteristics. Verify Nyquist's result for the variation of noise with resistance, and compare absolute value with calculation.

4. *Radio receiver noise.*

Set up a saturated diode as a noise source (shot effect) of known strength. Measure the noise factor of a radio receiver.

5. *Cloud chamber.*

Examine conditions for track formation and photography. Measure β ray spectrum of a radioactive element by measuring track curvatures in a magnetic field.

6. *Fabry Perot Interferometer.*

Set up interferometer crossed with prism spectrograph and photograph interference pattern of Ne spectrum. Determine accurate wavelengths by the " method of exact fractions."

7. *Zeeman effect.*

Obtain Zeeman patterns for the Ne spectrum, using a Fabry-Perot interferometer. Obtain e/m from a singlet line, and investigate a case of " anomalous " splitting.

8. *Tracks in photographic emulsion.*

Produce thorium stars in a " nuclear research " emulsion, and find track lengths and probability of various disintegrations.

9. *Fluxgate.* (Saturation magnetometer.)

Use a mumetal wire, magnetized to saturation, to measure the horizontal field in the laboratory. Ref. Parnum. *J.I.E.E.* **93** (1), 70, 1946.

10. *Wave guides (10 cm. waves).*

Set up wave-guides driven by a klystron oscillator. Compare wavelength in guide and on a coaxial line. Measure dielectric constant of a perspex slab terminating the guide.

11. *Transmission line (1 m. waves).*

Set up a transmission line driven by a Lecher wire oscillator. Examine effect of various terminating impedences on the standing waves. Match a line into a load. Measure dielectric constant of transformer coil.

12. *Millikan experiment, and Brownian motion.*

Investigate motion of a charged oil drop in electric field. Find charge on drop and deduce value for electronic charge.

Study random horizontal motion of an oil drop held suspended in a Millikan condenser. Determine Avogadro's number N.

13. *α-particles.*

Count α-particles from a radioactive source, using a small ionization chamber and linear amplifier. Plot Bragg ionization curve.

14. *Servo system.*

Set up a position-control servo, using stabilization by velocity feedback or time derivative of misalignment. Examine amplitude and phase of harmonic response as a function of frequency. Examine transient response.

15. *Rayleigh interferometer.*

Set up the interferometer and use it to find the refractive indices of air and hydrogen.

16. *Foucault Knife Edge—the Schlieren method.*

Set up apparatus to detect small changes of refraction index by the Schlieren method. Examine defects of a lens.

17. *Raman effect.*

Photograph the Raman spectrum of carbon tetrachloride excited by mercury arc spectrum. Analyse the spectrum and determine the infra-red frequencies.

18. *Photocell.*

Determine the relative sensitivity of a photocell to different wavelengths using a Tungsten lamp of known colour temperature.

19. *Magnetostriction.*

Investigate change of length of a nickel specimen on magnetization, using Newton's ring interference.

20. *Photomultiplier.*

Set up a photomultiplier cell, determine its absolute sensitivity for flashes of light. Investigate scintillations produced by α-particles in Zinc Sulphide screen.

21. *Coincidence counting.*

Set up a cosmic ray triple-coincidence telescope. Investigate absorption of cosmic rays, efficiency of a counter.

22. *Properties of Geiger counter.*

Set up time-base circuit to investigate dead time after a pulse and recovery phenomena.

23. *Electrometer valve.*

Set up an " acorn " pentode as an electrometer valve and determine minimum current measurable. Measure an ionization current.

24. *Viscometer.*

Set up a concentric cone viscometer. Calibrate with a " Newtonian " fluid and investigate viscosity of an " anomalous " liquid as a function of rate of shear.

25. *Sound intensity.*

Calibrate a microphone over a frequency range, using a Rayleigh disc in a stationary wave system.

26. *Ultrasonic waves.*

Determine velocity of sound in a gas, using stationary waves from an ultrasonic quartz oscillator.

27. *e/m for electrons.*

Use the Busch helical focusing method in a solenoid.

28. *Schering bridge.*

Set up the bridge and use it to determine dielectric constant and power factor of a liquid dielectric.

29. *Specific Heat.*

Investigate variation of specific heat of copper from liquid air to room temperature, using a vacuum calorimeter.

30. *Stellar Interferometer.*

Set up a model of Michelson's stellar interferometer and use it to find the diameter of a distant lamp filament.

31. *Spectroscopic comparison of atomic masses.*

Compare the wavelengths of lines in the H and D spectra using a grating spectrograph. Determine either the ratio of the masses of the

proton and the deuteron or the ratio of the masses of the proton and electron.

32. *Ripple tank.*

Investigate the effect of contamination on the surface tension of water.

33. *Velocity of sound.*

Measure velocity of sound in free air, using phase comparison method.

34. *Amplifier square wave response.*

Build a two-stage amplifier and examine square wave response with and without feedback. Calculate harmonic response.

35. *Wind Tunnel (for specialists in Fluid Motion).*

Calibrate wind tunnel and auxiliary equipment ; study air flow round a cylinder.

APPENDIX II
DESIGN STUDIES

1. Gravitation apparatus

General design to follow Boys—(see any book on Properties of Matter).

Points to be considered :

Materials for suspended masses and attracting masses.

Material for suspension.

Mechanical design to ensure that suspension is not disturbed by motion of attracting masses.

Optical design of reading system.

Sizes of parts—consider :

Sensitivity ;

Time of swing and effect on method of reading ;

Strength of suspension.

Operational design :

Precautions against convection ;

What is effect of thermal noise (Brownian motion) ;

Would there be any advantage in using a deflection amplifier.

2. Optical-Electronic apparatus for determining "*g*" by free fall.

It has been suggested that "*g*" could be determined by timing the free fall of a suitable body, and that the method could compete with established pendulum methods. Find what accuracy is claimed for the latter ; assume reasonable dimensions for the free fall apparatus, and estimate the accuracy of length and time measurements required.

If the proposal still looks practicable, sketch out the mechanical arrangements for releasing and catching the falling body, the optical system for illuminating a photocell and making the falling body cut off the light abruptly, and the amplifier required to produce a voltage signal from the photocell output.

The timing element will in any case be an oscillating quartz crystal : alternative methods for recording the time are :

(1) Count cycles from the oscillator in a scale-of-two or scale-of-ten arrangement, and devise a "gating" circuit under the control of the photocell to convect oscillator and counter during the fall.

(2) Use the oscillator to drive a circular time base on a cathode ray tube, use the photocell pulses to brighten the trace and produce time marks. The time must be otherwise determined to within one revolution of the time base.

Work out circuits for one of these methods.

3. Magnetometer for determining magnetization of weakly magnetic rocks (Induction apparatus)

The rock specimen is rotated inside a coil which is connected to an amplifier, and the induced e.m.f. at the rotation frequency is observed. It can be separated from the e.m.f.s at other frequencies by means of a synchronous rectifier. In practice large disturbing effects are produced by stray fields, and these must be compensated since they would overload the amplifier. Consider a coil whose cross-section is indicated with the specimen regarded as an oscillating dipole at its centre. Calculate the signal and the resist-

ance noise and see how the coil should be designed for greatest signal-noise ratio. Using a pair of such coils, estimate the compensation achieved against stray fields—a typical stray field might be introduced by a long wire carrying 10 amp. 10 metres away. Sketch a mechanical design for the apparatus.

4. RAYLEIGH'S REFRACTOMETER TO MEASURE THE REFRACTIVE INDEX OF A GAS TO THE HIGHEST POSSIBLE ACCURACY

A Rayleigh refractometer is required to measure the refractive index of a gas to the highest possible accuracy. The interferometer is described in Williams's *Applications of Interferometry* and in most textbooks on physical optics. A simple form exists in the 3rd year laboratory and may be examined. You are recommended to consider the following points :

General optical design.

Fiduciary marks to which motion of fringes is to be referred.

Required homogeneity of light source.

Would anything be gained by photo-electric methods of observation.

How is the gas concentration to be measured.

What accuracy can be achieved with a manometer and what precautions must be taken.

What is the effect of temperature irregularities, and what should be done about it.

Estimate what fractional accuracy you could expect in $(n-1)$.

Note.—The effect of impurities in the gas is likely to be serious, and the provision of a pure sample is a chemical problem differing for each gas. Assuming that you are working with nitrogen, estimate the tolerable proportions of various impurities.

5. PRISM SPECTROGRAPH USING A PHOTO-ELECTRIC CELL TO GIVE THE INTENSITY RATIO OF TWO CLOSE LINES

A prism spectrograph is required to give the ratio of intensities of two lines about 1 Å apart at $\lambda = 4500$ Å. A photo-electric cell (or cells) is to be used as the final detector.

Sketch the optical design of the spectrograph—the resolving power must be sufficient and the linear dispersion must allow the light in the lines to be separated.

Calculate roughly the light falling on the photocell—you may assume that the luminous energy in a line is equivalent to that in a 1 Å element of the spectrum of a black body at 2850°K. Assuming that the cathode sensitivity of a photocell corresponds to a quantum efficiency of 10%, estimate the cathode current and consider how you would measure it.

6. APPARATUS AND METHOD OF EXPERIMENT TO FIND THE VISCOSITY OF AIR WITH HIGH ACCURACY

Design an apparatus and method of experiment to find with high accuracy the viscosity of air by measuring the drag between concentric cylinders of which one is rotating. You should consider :

What range of rotational speeds can be used without encountering turbulent flow.

What guard ring arrangements are required to eliminate end effects.

How is the speed of the rotating cylinder to be controlled and measured.

How is the drag couple to be measured.

Will a damping couple be required and how can it be provided.

The Work of the Non-Destructive Testing Group

By E. G. STANFORD, M.Sc., Ph.D., A.M.I.E.E., A.Inst.P.

(*Head of Physics Department, Aluminium Laboratories Ltd.*)

THE EXAMINATION of materials and engineering components by methods which do not involve their destruction has become a technology which demands the active interest of a number of scientific and professional societies. Foremost among these societies has been The Institute of Physics which, through the efforts of its Non-Destructive Testing Group, has taken a leading part in stimulating interest in non-destructive testing and in aavancing the science of the subject.

When the application of scientific principles to the solution of industrial problems acquires the status of a technology, the attraction of quick returns for money and effort creates the temptation to pursue the technology and to neglect the scientific background. If the neglect of the scientific background is allowed to persist, real progress in the technology is soon brought to a standstill. To face this fact squarely, and to take up the challenge contained in it, requires a deal of courage on the part of the Non-Destructive Testing Group, for it has reached a stage in its career at which it could take advantage of the enthusiasm of the large following of technologists and, by catering solely for them, so expand its membership as to be able to blossom forth as a National Society of Non-Destructive Testing. But the Group belongs to The Institute of Physics and its duty is, therefore, that of maintaining interest among physicists in the work it is trying to do ; its efforts must be directed to the very much more difficult task of advancing knowledge in those branches of Physics which form the basis of non-destructive testing, and if it is successful in this pursuit then, and only then, will progress in the technology be assured.

A little more than a year ago the Board of the Institute drew the attention of the Group Committee to the danger of allowing its choice of papers, lectures and discussions to be unduly influenced by the interests of the technologist at the expense of those of the physicist. The Board recognized that there might be a need for an independent National Society of non-destructive testing, and was prepared to assist, as far as it could, in the formation of such a society. It considered, however, that the Non-Destructive Testing Group should devote its attention to Physics, and it pointed out that, by so doing, the Group would be fulfilling the most important function of feeding scientific information to those responsible for the development of the technology.

The Group Committee, recognizing the danger, has, during the past year, reviewed the field covered by the physics of non-destructive testing and has reached the conclusion that almost every branch of Physics is involved. For a definition of the scope of its work the Committee has had to accept, therefore, the broad statement that it shall take an interest in any physical research which can be shown to be relevant to non-destructive testing. In accepting this definition the Committee is aware of the fact that the recognition of the relevance to non-destructive testing of any physical research will be, in perhaps most cases, its own responsibility, since it can hardly be expected that research workers who are not directly concerned with non-destructive testing will see,

in the results of their work, information which is of value to those who are so concerned.

In writing this article it is the intention to describe the present Committee's conception of the type of work involved in the physics of non-destructive testing. It is hoped that the description itself will promote discussion and that the article will enable all members of the Institute to gain some idea of what the Group is trying to do, so that in its future activities it may count on their support, advice and guidance.

The decision has been taken that, for the time being, the Group shall give emphasis to matters connected with the testing of solids, solids being classified either as metals or as non-metals. This restriction has been adopted for the simple reason that those responsible for the organization of the Group are concerned primarily with solids. The testing of liquids and gases must not be overlooked, however, and in this connection there is a need for those members of the Institute who are interested in liquids and gases to join the Group with the object of exerting their influence on its outlook.

The Group Committee has approached the study of the physics of testing solid materials from the standpoint that testing is carried out to ascertain that they contain no defects which would be detrimental to their behaviour in service, to check that their dimensions and surface condition meet requirements, and to determine their properties.

Arrangements have been made for certain members of the Group to publish review articles on the various non-destructive methods. Against the background of the techniques, these reviews will draw attention to the gaps in physical knowledge which hamper progress in the techniques, and, thereby, will serve, it is hoped, as guides to the Group in its choice of subjects for discussion

The five principal techniques—magnetic. testing, radiographic examination, ultrasonic testing, eddy current testing and penetrant testing—constitute the technology of non-destructive testing. Of these, magnetic testing, radiographic examination, and penetrant testing were the first in the field, and because of their quite outstanding success in the detection of defects a tendency has arisen to regard non-destructive testing as being concerned only with "crack detection." This, of course, is not the case, especially since the coming of ultrasonic and eddy current testing.

The success achieved in the detection of defects has provided the problem of assessing the significance of defects in terms of service behaviour. The classification of defects and the seriousness of their presence in materials is a subject about which there is little information, and the Group will do its utmost to encourage investigators who attempt to study the effects of different types of defect on the structural behaviour and properties of materials subjected to service conditions.

Outside the now well-established field of flaw detection non-destructive testing has gained little acceptance ; but the checking of dimensions and the examination of surface condition nearly always involve some kind of non-destructive test. For this reason the Group is interested in problems of metrology and in the study of surfaces. In the latter case the kind of interest which the Group has is illustrated by the following examples : Methods of measuring the flatness and roughness of surfaces, methods of measuring the cleanliness of surfaces, methods of measuring the degree of adhesion of films to surfaces, methods of measuring the thickness of films, methods of measuring the properties of films and, in particular, methods which can be used to show to what extent surface properties can be related to the properties of the sub-surface material.

In its work on the review of the physics of non-destructive testing, the Group Committee has, so far, concentrated most of its attention on the measurement of the properties of materials, and, as a result, the programmes arranged for this present Session and for the 1956–57 Session contain a number of papers connected with the investigation of properties.

In industry the measurement of physical properties involves either laboratory examination of specimens taken from a batch of material or "on site" examination of all

the material in a batch by methods which must be non-destructive.

In Table I a number of physical properties are listed which are determined by these two types of testing procedure. The table serves to show that for the determination of the majority of properties test specimens are required, and, depending on which properties are of interest, the test procedure may involve the destruction of the specimens, or some change in the material and shape of the specimens without destroying them, or the specimens may not be changed in any way whatever.

In almost all the uses to which materials are put, their mechanical strength and mechanical behaviour are important factors —usually the most important factors—to be considered. Therefore, as can be seen by reference to Table I, the properties which are

TABLE I

Column I	Column II
Tests in which Specimen is Destroyed	*Tests in which Specimen Structure and Shape is, or may be, Changed*
Tensile Strength	Thermal Conductivity
Fatigue Range	Specific Heat
Ductility	Yield Strength
Impact Resistance	Creep Resistance
Corrosion Resistance	Thermal Expansion
	Work Hardening Characteristics
	Precipitation Hardening Characteristics
	Recrystallization Characteristics
	Visco-Elastic Properties

Column III	Column IV
Tests in which the Specimen is not Changed	*Non-Destructive Tests*
Electrical Conductivity	Dimensions
Density	Defects
Magnetic Permeability	Electrical Resistivity
Magnetic Hysteresis	Density
Damping Capacity	Magnetic Properties
Elastic Moduli	Elastic Moduli
Magnetostrictive Properties	Surface Properties
Optical Properties (surface properties)	Thermo-electric Properties
Thermo-electric Properties	Hardness
Grain Size	
Texture	
Hardness	

of greatest interest are those which are determined from tests in which the specimens are destroyed. If the properties of materials are quoted from results of tests made on such specimens, then the assumption has to be accepted that all the material in a batch has the same properties as the specimens taken from it. Manufacturing conditions are such that, at the present time, this may be a very reasonable assumption to make, but as engineering design advances, and as materials are required to operate under increasingly severe conditions of service, it is becoming more and more essential to make absolutely certain that batches of material are completely uniform in properties throughout. For this certainty to be established the procedure envisaged by the Group in industrial testing is that of determining the properties of specimens taken from a batch of material and then subjecting the remainder of the material in the batch to a series of non-destructive tests which will indicate its degree of uniformity.

In this connexion, then, the problem facing physicists concerned with non-destructive testing is that of devising tests which will give an assessment of the uniformity of large quantities of material, and, since such an assessment might well involve the examination of a considerable proportion of the output of a manufacturing plant, the testing speed will have to match the rate of production.

There are a number of instruments already in use in industry for assessing the uniformity of materials. These instruments operate on the principle that changes in chemical composition and/or, changes in structural components (such as grain size) cause a variation in physical properties ; this variation can be detected non-destructively if the design of the instruments is based on the measurement of such physical properties as are listed in column IV of Table I. Electrical properties (resistivity) and magnetic properties are the ones most commonly chosen for this purpose. The difficulty with the use of instruments of this kind is that of interpreting the meaning of observed changes in physical properties when a number of changes in composition and structure occur simultaneously. Furthermore, having detected that some change has taken place, the problem of identifying its significance, in terms of composition and structure, is followed by the problem of assessing just what effect it will have on other properties—particularly on those properties which can be determined only by destructive tests.

Until physical properties are themselves better understood, the solution to these problems has to be attempted by empirical means and, for the present, the approach to be adopted by the Group is that of encouraging discussion on the effects on physical properties of variations in the composition and structure of materials. From the information gained by these discussions it will become evident whether, and to what extent, measurements of physical properties can be used as a means of detecting and identifying such variations. In parallel with this type of activity the Group proposes to invite research workers to present papers on work which has been carried out with the object of discovering whether empirical relationships can be set up between those properties which are determined by means of test specimens and those which can be measured in such a way as to make them a suitable basis for non-destructive tests.

The Group Committee realizes that this empirical approach is somewhat naïve. There is a great deal about the structure of materials which is not known ; the task of collecting data showing the relationships between physical properties and changes in composition and structure is therefore an undertaking of considerable magnitude. The Group expects that attempts to establish such relationships will often produce diagrams with the points plotted on them looking like the night sky in January. Furthermore, in what has been written here, the properties of metals have been foremost in mind, but equal importance must be attached to non-metals the structure of which is, in most cases, so complex that the normal conception of mechanical properties is often quite meaningless because their mechanical behaviour is extremely varied and markedly dependent upon so many factors.

The Group is in no doubt as to the difficulty of the field in which it proposes to extend its activities, but, nevertheless, a great deal of work of the type required has either been carried out or is in progress at the present time. At the 1956 Summer Meeting of the Group, which is to be held at Bristol University from July 12 to 14, a first review of the newer aspects of the physics of non-destructive testing is to take place, and discussions will be held on papers describing work carried out on the following subjects :

The structural changes which take place in metals during fatigue.

The relationship between mechanical damping in metals and fatigue.

The relationship between electrical resistivity and the mechanical properties of metals.

The effects of variations in composition and structure of metals on their magnetic properties.

The application to non-destructive testing of the methods of nuclear magnetic resonance.

The use of optical fluorescence spectroscopy in non-destructive testing.

The measurements of the elastic constants of metal crystals.

The testing of plastics.

These subjects chosen for the Summer Meeting are mentioned to illustrate the kind of work which the Group has in mind. In promoting interest in the physics of non-destructive testing it is the hope of the Group that the lectures, papers and discussions arranged will not only provide information of use to those responsible for the development of testing techniques but will also provide information of use to those physicists whose aim it is to discover why materials possess their particular properties.

Note on Medical Testing.

It has often been remarked that medical testing has to be non-destructive. This field should perhaps provide a most important activity of the Non-Destructive Testing Group, and under the guidance of Professor C. B. Allsopp, of Guy's Hospital, the Group has begun to plan its work on medical physics. At the 1956 Summer Meeting a lecture will be given, by Professor Allsopp, on Medical Testing.

In conclusion the author wishes to express his thanks to the members of the Group Committee and of the Group's Physics Subcommittee for their help, so willingly given, in the task of reviewing the physics of non-destructive testing, and, in connection with the publication of this article, the author is indebted to Dr. J. Thewlis, Mr. W. E. Schall and Mr. B. R. Byrne for their valuable advice.

Branch News

Meeting at Leatherhead, Wednesday, November 9, 1955

The Branch Committee has for some time past been conscious of the desirability of holding meetings away from the centre of London and opportunity was taken on November 9 last to hold a meeting at Leatherhead, Surrey, which proved most successful.

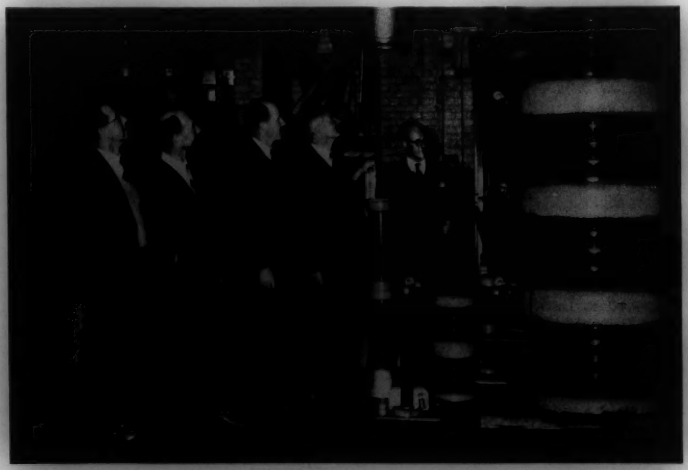
During the afternoon one party of members visited the British Coal Utilization Research Association, whilst a second group visited the Central Electricity Research Laboratories where considerable extensions have recently been opened. At the conclusion of these visits the two groups of members met for an excellent tea which was provided in the C.E.R.L. Reading Room after which a lecture meeting was held in the new Conference Room.

Dr. J. S. Forrest, Branch Chairman and Director of C.E.R.L., opened the meeting with a short account of the various research activities now taking place in the Leatherhead district. In addition to the organizations taking part in the day's proceedings he drew attention to the Food Industry Research Association, the British Electrical Development Association Testing House and the new Laboratories of the Electrical Research Association now nearing completion. The Branch Chairman then introduced Dr. V. G. W. Harrison (*Fellow*) of the Printing, Packaging and Allied Trades Research Association, who gave a talk on "Some Problems of Half-tone Reproduction."*

All Branch members who visited Leatherhead are grateful to the three organizations contributing to the success of the meeting.

B. S. COOPER.

* To be published in the BULLETIN



A group of members in the high voltage laboratory at C.E.R.L. Leatherhead (l. to r.: Mr. G. W. Warren, Mr. B. S. Cooper, Dr. A. J. Maddock, Dr. T. B. Rymer and Dr. J. S. Forrest).

Reviews of Books

NATIONAL GALLERY 1938-1954

London : The Trustees of the National Gallery. Pp. 124, Price 12s. 6d.

Periodical reports which appear from time to time on our national institutions are usually of limited interest to those not immediately concerned since statistics and officialese rarely make for good reading. The report entitled "National Gallery 1938-1954" is quite different in this respect because the story of these eventful years appears in the form of a 124 page book containing 21 plates, nine of which are in colour, and is told in a manner likely to have some appeal outside what are commonly called "artistic circles." This is for the very good reason that the Trustees believe the time has come for every responsible citizen to realize the plight of the nation as a collector of works of art when first class paintings come into a market which is probably the most sensitive of all to inflationary conditions. The situation is that without a substantial increase in funds for the purchase of major works it is going to be difficult for the Gallery to maintain its position as "the best balanced and most representative, if not the most extensive, collection of paintings in the world." This is not, however, the place to discuss such matters but rather to deal with those aspects of the report which are of more direct interest to physicists : the growth between 1938 and 1954 of the Scientific Department under F. I. G. Rawlins (a Fellow of the Institute), and the establishment of the Conservation Department, the staff of which includes N. Brommell (an Associate of the Institute).

At the beginning of the period under review the Scientific Department was faced with the problem of protecting the literally priceless collection in time of war. What was achieved, which is briefly outlined in the report, is now acknowledged by the entire world to have been as near to perfection as could be—a proud record in view of the catastrophies that did occur in other countries. In fact, while inside a mountain in Wales, the paintings were housed in a better environment than at any time in their previous history. The experience with air conditioning thus gained proved beyond doubt that constancy of relative humidity obviates one of the most potent causes of decay in objects composed as paintings are of a variety of hygroscopic materials such as wood, canvas and animal glue.

With the post-war return to Trafalgar Square the case for air-conditioning had become incontrovertible and the installation of the necessary plant was soon put in hand by the Ministry of Works. For economic reasons—conditioned air could not be circulated without completely remodelling the lofty rooms—progress in this direction has been slow. By 1950, however, one such transformed room was opened to the public and it is now possible to visualize what the Gallery will be like in the future. The essential architectural feature of the remodelling is a new relatively low ceiling fitted with lay-lights, which makes it possible at the same time to improve the artificial lighting. The lighting which had been installed in 1935 took the form of tungsten bulbs in lantern pendants which produced a curious artificial effect with certain paintings, presumably because only a fraction of picture elements such as paint texture, burnished gold, coarsely ground pigments, and so on were so orientated as to reflect to the observer from relatively compact sources. In the modern system a battery of fluorescent tubes, together with some tungsten lamps, all concealed in the ceiling, give adequate diffuse illumination with the right degree of directionality. Quite apart from the question of colour temperature, paintings vary greatly in the kind of source which is most effective and compromise is inevitable if it is to serve an

altar-piece, a Rembrandt portrait and an impressionist landscape.

The art of restoring paintings is an old one, carried out with great skill by practitioners who have an intimate, if empirical, knowledge of the behaviour of materials ; this knowledge is, however, capable of extention and rationalization with the aid of science and so the sentence " What actually takes place when a solvent comes in contact with a varnish or a medium or a pigment is still fundamentally a mystery " (p. 60) hardly represents the outlook of to-day in view of recent researches at the National Gallery and the Courtauld Institute in this country and at the Mellon Institute and Fogg Museum in the U.S.A. As in the case of some of the industries based on ancient crafts, the impact of science has tended to follow a familiar pattern, a pattern which however became highly coloured in the case of the National Gallery by the well known controversy over cleaned pictures which occurred in the press and elsewhere during 1946-1947. This controversy, and the Weaver Report based on a private inquiry into the matter, clearly demonstrated the inadequate state of our knowledge of the cleaning process and provided a powerful stimulus for more fundamental research. The reviewer, in a memorandum sent to the Gallery authorities in 1949, theoretically examined the process and its effects on paint in the light of the diffusion of solvents into gels and consequent swelling and softening of paint films. That there was at that time apparently little published data on the swelling characteristics of the heterogeneous natural products present in the typical oil painting clearly indicated that the next stage should be an experimental determination of such properties as rate of swelling. In 1951, through the generosity of the Nuffield Foundation in endowing two scholarships at the National Gallery, fundamental research of this kind became possible. One of the scholars proceeded to use an optical interference method to observe rates of swelling and to determine rates of evaporation of solvents by means of a micro-balance while the other embarked upon the isolation and identification of the constituents of dammar resin by means of chromatography. At the Courtauld Institute the swelling and deswelling of dried oil-films has been investigated using a parallel plate viscometric method. It is now possible to examine the data in terms of the cohesive energy density theory of the solution of polymers in so far as it is applicable to dried oil films ; the value of the solubility parameter of linoxyn which has been determined will, it is hoped, make it possible, if not to find improved solvents or solvent mixtures, at least to assess the qualities of those in use at present.

The Report also gives an account of other developments designed to enhance the significance of the Scientific Department : a senior scientific officer and an experimental officer were added to the staff and steps were taken to ensure closer relationship with the Conservation Department. The laboratory is naturally called upon to deal with a variety of *ad hoc* technical questions arising from conservation operations and to carry out routine scientific examination of paintings ; it is evident in the account that this task has been accomplished with real advances in technique, both on the physical and chemical side. The methods employed include photography with various radiations (a noteworthy example of an infra-red photograph is reproduced), colorimetry, microsectioning, and microchemical analysis.

Finally, the report is of interest to scientists because of the tribute it pays to the distinguished Scientific Advisory Committee for its vigilance and guidance in all the varied efforts directed towards ensuring the physical well-being of the collection.

S. Rees Jones.

WORKED EXAMPLES IN ENGINEERING THERMODYNAMICS

By H. J. Smith and J. W. Harris

London : Macdonald & Company Ltd. Pp. 495 + x. Price 35s.

About 300 questions from past examinations of, for example, London University, the Institution of Mechanical Engineers

and the Higher National Certificate are grouped under twenty chapter headings covering steam and combustion cycles, heat transfer and refrigeration. Each group of questions is given first followed by note-form solutions with plenty of clear diagrams—usually p-v and T-ϕ or H-ϕ. The notation has been carefully confined to the appropriate British Standards which is a very useful discipline to prevent the multiplicity of notations which arise when each writer has his own pet symbols. The Fahrenheit Temperature scale is used throughout which is, unfortunately, very popular with Engineers but helps to keep the Physicist on his toes to use the right conversion factors.

The solutions given to the problems contain short pieces of explanation and references to various textbooks for fuller explanation without however giving the actual page of the reference. The authors imply in their preface that the idea of the book is that the student, having attended lectures on the subject or read a standard Heat Engines textbook, should work the examples first and then look up their correct solution, so that the book is to supply a kind of long range " tutorial " teaching method. It is certainly true that a student strong minded enough to do this would have a very good grasp of the subject but the present reviewer feels that crowded University courses do not leave the student enough time to make full use of such a book and that after he passes his examination he will prefer to have a standard textbook on his shelves for reference purposes. Nevertheless to have such a book in the library of an Engineering Department teaching Heat Engines would obviously be useful both to students and their supervisors for checking knowledge of parts of the field.

One point which these questions bring out clearly is the way in which thermodynamics of steam engines has been taught without taking account of the thermodynamics of the boiler. Neither a Carnot cycle taking in its heat all at one temperature nor a Rankine cycle is the best way of making use of the heat of hot combustion gases which is distributed over a wide range of temperatures, but the increase in entropy in the heat transfer between the combustion gases and the steam is never mentioned. Perhaps the advent of the gas turbine will make the classical steam thermodynamics more realistic.

M. W. THRING.

The following reports have also been received :—

1956-1957 Postdoctorate Fellowships. Canada : National Research Council. Pp. 95 + vii.

United Kingdom Atomic Energy Authority : First Annual Report 1954-55. London : Her Majesty's Stationery Office. Pp. 35 + vii. Price 2s.

A Career for the Graduate in Industry. London : Federation of British Industries. Pp. 23. Price 2s

Industry and the Graduate. London : Federation of British Industries. Pp. 29. Price 2s.

National Physical Laboratory : Report for the Year 1954. London : Her Majesty's Stationery Office. Pp. 98 + viii. Price 4s.

Proceedings of the Commonwealth Oceanographic Conference 1954. London : The Syndics of the Cambridge University Press. Pp. 93. Price 7s.

Safety in Mines Research 1954 : Thirty-third Annual Report. London : Her Majesty's Stationery Office. Pp. 93. Price 4s.

British Electricity Authority. Seventh Report and Accounts 1954-55. London : Her Majesty's Stationery Office. Pp. 242 + viii. Price 10s.

The British Iron and Steel Research Association : Annual Report 1954. London : The British Iron and Steel Research Association. Pp. 144.

The Chartered Electrical Engineer (Electrical Engineering as a professional career). London : The Institution of Electrical Engineers. Pp. 26. *Gratis.*

Forthcoming Institute Meetings

Feb. 14 Electronics Group — At the Institute's House, 5.30 p.m.
"*Germanium and Silicon Crystals and Devices*"
DR. E. BILLIG

Feb. 15 London and Home Counties Branch — At the Institute's House, 6.30 p.m.
"*Explosions*"
DR. STEWART PATERSON
Preceded by the
BRANCH ANNUAL GENERAL MEETING

Feb. 15 Midland Branch — At the University of Birmingham, 5.15 p.m.
"*Colour*"
PROFESSOR W. D. WRIGHT

Feb. 27 Education Group — At the Institute's House, 6 p.m.
"*Newton's Conception of Scientific Method*"
MR. A. C. CROMBIE

Feb. 29 Midland Branch — At Regent House, Birmingham, 7 p.m.
"*Electrical Contacts*"
PROFESSOR F. LLEWELLYN JONES, F.Inst.P.

Mch. 2 South Wales Branch — At the University College of Swansea, 5.15 p.m.
"*Some Lighting Problems in Road Research*"
MR. G. GRIME, O.B.E.

Mch. 5 Scottish Branch — At the University of Edinburgh, 5.15 p.m.
"*Television Technique Applied to Scientific Observation*"
PROFESSOR J. D. McGEE, O.B.E., F.Inst.P.

Mch. 6 Scottish Branch — At Queen's College, Dundee, 5.15 p.m.
"*Exploration of the Upper Atmosphere Using Rocket Vehicles.*"
PROFESSOR H. S. W. MASSEY, F.R.S.

Mch. 6 Scottish Branch — At the Royal Technical College, Glasgow, 7.15 p.m.
"*Television Technique Applied to Scientific Observation*"
PROFESSOR J. D. McGEE, O.B.E., F.Inst.P.

Mch. 7 Scottish Branch — At the University, Aberdeen, 7.30 p.m.
"*Television Technique Applied to Scientific Observation*"
PROFESSOR J. D. McGEE, O.B.E., F.Inst.P.

Mch. 13 Electronics Group — At the Institute's House, 5.30 p.m.
"*Some Recent Studies on Electrical Contacts*"
PROFESSOR F. LLEWELLYN JONES, F.Inst.P.
preceded by
GROUP ANNUAL GENERAL MEETING

Mch. 13 Midland Branch — 2.30 p.m.
Visit to Taylor, Taylor and Hobson, Ltd., Leicester
followed by
"*Fine Measurements*"
MR. J. R. ADAMS
(Number limited to 25. Application to be made to the Branch Secretary)

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON JANUARY 17, 1956

An asterisk (*) indicates transfer from another grade

FELLOWS

Bingham, Rowland Trevor Wellard, M.Sc., Instructor in Physics, Swinburne Technical College, Melbourne, Australia.

*Cannon, Cyril George, B.Sc., Group Leader, Spectroscopy and Fundamental Physics Group, British Nylon Spinners Ltd., Newport, Mon.

*Cockett, Alfred Horace, B.Sc., Senior Physicist, Research and Development Department, British Oxygen Co. Ltd., London.

Davis, John Hancock, B.Sc., Ph.D., Senior Lecturer, College of Technology, Birmingham.

*Hatfield, Percy, M.Sc., Ph.D., Group Leader, British Nylon Spinners Ltd., Newport, Mon.

*Heavens, Oliver Samuel, B.Sc., Ph.D., Lecturer in Physics, University of Reading.

*Lewis, Gething Morgan, M.Sc., Ph.D., Lecturer in Physics, University of Glasgow.

*Marshall, Donald George, B.Sc., Ph.D., Manager, Physical Research Division, Dunlop Rubber Co. Ltd., Birmingham.

*Townsend, George Boris, B.Sc., Senior Scientific Staff, Research Laboratories, General Electric Co. Ltd., Wembley, Middlesex.

ASSOCIATES

Acton, Eric William Vickers, M.Sc., Physicist, General Electric Co. Ltd., Wembley, Middlesex.

Ainsworth, Thomas Somner, B.Sc., Head of Laboratory Group, Siemens Brothers & Co. Ltd., London.

Arridge, Robert Graham Chadwick, B.A., B.Sc., Technical Officer, Development Section, British Nylon Spinners Ltd., Newport, Mon.

*Banks, Alec John Frederick, M.A., Williamson Cliff Ltd., Stamford, Lincs.

*Bicknell, Ronald William, M.Sc., Physicist, Plessey Co. Ltd., Towcester, Northants.

*Bridge, Harry, B.Sc., Physicist, Research Department, Pilkington Brothers Ltd., St. Helens, Lancashire.

*Brook, Geoffrey, B.Sc., Ph.D., Lecturer in Textile Industries, University of Leeds.

Caff, Wilfred Reginald Met, M.Sc., Senior Physics Master, Manchester Grammar School.

*Ciddor, Philip Emmanuel, M.Sc., Research Officer, Division of Metrology, Commonwealth Scientific and Industrial Research Organization, Sydney, Australia.

Copisarow, Alcon Charles, B.Sc., H.M. Scientific Attaché, British Embassy, Paris.

Davis, Gerald Thomas, B.Sc., Technical Officer, British Nylon Spinners Ltd., Newport, Mon.

Davies, Leslie John, B.Sc., Scientific Officer, British Ceramic Research Assn., Stoke-on-Trent.

Davies, Robert Desmond Peregrine, B.Sc., Lecturer in Physics, Portsmouth College of Technology.

Dickinson, Norman, B.Sc., Scientific Officer, Admiralty Research Laboratory, Teddington, Middlesex.

*Dudley, Albert, B.Sc., Research Officer, British Cotton Industries Research Association, Manchester.

*Flanagan, Terence Patrick, B.Sc., Electronic Instrument Designer, Marconi Instruments Ltd., St. Albans, Herts.

Forshaw, Kenneth George William James, B.Sc., Physicist, Telephone Manufacturing Co. Ltd., Orpington, Kent.

*Gemmell, William, B.Sc., Research Physicist, S.W. Regional Metropolitan Hospital Board, London.

*Gidley, John Arthur Frederick, B.Sc., Technical Officer, Imperial Chemical Industries Ltd., Birmingham.

*Greenwood, Kurt, B.Sc., Principal Physicist, Weaving Department, British Rayon Research Assn., Manchester.

*Hardy, John Edward, B.Sc., Senior Physicist, British Oxygen Co. Ltd., London.

*Healey, Ernest Michael, B.Sc., Scientific Officer, Royal Aircraft Establishment, Farnborough, Hants.

*Holden, Charles, B.Sc., Research Physicist, United Steel Companies Ltd., Rotherham.

*Holt, Arthur Denys, M.Sc., Electronic Engineer, Electric and Musical Industries Engineering Development, Hayes, Middlesex.

Hubbard, George Douglas, B.Sc., Research Physicist, Dunlop Research Centre, Birmingham.

Madoc Jones Dewi, B.Sc., Ph.D., Technical Officer, British Nylon Spinners Ltd., Newport, Mon.

Mallard, John Henry, B.Sc., Teacher of Physics, College of Technology, Northampton.

*Moody, Brian Edgar, M.A., Head of the Physics Department, Research Laboratories, United Glass Bottle Manufacturers Ltd., London.

*Ogilvie, Keith William, B.Sc., Ph.D., Research Fellow, University of Sydney.

Owen, John Miller, B.Sc., Physics Master, Mt. Grace Secondary Comprehensive School, Potters Bar, Middlesex.

*Patridge, Alan Torrington, B.Sc., Physicist, Mullard Radio Valve Co. Ltd., Salfords, Surrey.

*Penhale, Leighton George, B.Sc., Research Physicist, Research Laboratories, The Plessey Co. Ltd., Northants.

Raghavachari, S., M.A., M.Sc., Lecturer and Head of Department of Physics, Madras Institute of Technology, Chromepet.

Rosenberg, Harold Max, B.Sc., D.Phil., Research Physicist, Clarendon Laboratory, Oxford.

Shapland, David J., B.Sc., Ph.D., Senior Aerodynamicist, A. V. Roe and Co. Ltd., Woodford, Cheshire.

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47 Students and 6 Subscribers were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE FEBRUARY, 1956, ISSUES

Journal of Scientific Instruments: Volume 33, No. 2

PAPERS

The temperature calibration of a high temperature X-ray diffraction camera. By J. A. Brand and H. J. Goldschmidt, F.Inst.P. (*The B.S.A. Group Research Centre, Sheffield*).

The accurate measurement, by a thermocouple, of the temperature of fibre specimens in an X-ray high-temperature camera, of the type containing a spherical furnace enclosure, is investigated. Factors affecting the calibration of the thermocouple are discussed, and it is shown experimentally that the chief cause of discrepancies is the abstraction of heat along the thermocouple wires. Methods for calibrating the thermocouple in position, and for reducing the correction required to a minimum, are presented.

A calorimeter for measuring energy absorption from pile radiation. By A. R. Anderson and R. J. Waite (*Atomic Energy Research Establishment, Harwell*).

An adiabatic calorimeter has been designed for the measurement of energy absorption from pile radiation. Some of the unusual problems encountered in this type of calorimetry are discussed. The preliminary work leading to a suitable design of calorimeter is summarized and full descriptions of the instrument and measurement techniques are given. Electrical calibrations of three samples with widely different thermal conductivities have demonstrated the satisfactory behaviour of the calorimeter over a wide range of power inputs. The results of some measurements in the Harwell pile BEPO are briefly discussed.

The principles and apparatus of the injection system of the Birmingham proton synchrotron. By C. A. Ramm, A.Inst.P. (*University of Birmingham*).

An outline is given of the principles used in the injection system of the Birmingham proton synchrotron which make the injection process relatively automatic and free from the necessity of a primary proton beam with an energy of great stability. A simple analysis is made of particle collection in the absence of the radio-frequency acceleration. The basic components and methods of monitoring the injection system are described.

An isothermal micro-calorimeter. By J. B. Stott (*School of Mines, University of Otago, Dunedin, New Zealand*).

A calorimeter is described which, although nearly isothermal and independent of the specific heats of the materials employed, can still be used over a wide range of temperatures and makes use of a bank of thermocouples to measure the heat evolved. An attempt is made to obtain the maximum theoretical sensitivity by making most of the heat produced pass down the thermocouples. The high rate of heat transfer down the thermocouple wires has made it possible to pass up to 15 ml./min of air through the calorimeter without affecting the sensitivity.

A cell for kinetic measurements of gas evolution from systems irradiated by fast electron beams. By C. B. Amphlett and T. F. Williams (*Atomic Energy Research Establishment, Harwell*).

By employing a mercury bellows manometer and balancing circuit it has been found possible to measure rapid rates of gas evolution from systems undergoing decomposition under fast electron bombardment from an electrostatic generator. The apparatus is reasonably robust, rapid in response, and gives reproducible results. Much slower rates of gas evolution can also be measured by the same technique.

Small angle X-ray diffraction unit. By C. R. Worthington (*Physics Department, University of Adelaide, South Australia*).

A small angle X-ray diffraction unit consisting of a rotating anode X-ray tube and an evacuated X-ray camera is described. The X-ray camera can resolve a spacing of 1000 Å with a separation of two lines per mm at the X-ray film. Photographs of the first twelve orders of moist collagen have been obtained, fully resolved, with exposures of less than one hour.

A wide range, recording, logarithmic photometer circuit. By P. Hariharan, A.Inst.P., and M. S. Bhalla (*National Physical Laboratory of India*).

The circuit described uses a photomultiplier tube operated as a range compressor, followed by a logarithmic amplifier, to obtain an accurately logarithmic response over an illumination range greater than 10^6 : 1. It can be utilized, in conjunction with a recording milliammeter or an oscillograph, for brightness *versus* time measurements wherever extreme brightness ranges are encountered.

A fast multiple coincidence circuit. By B. Collinge, A. W. Merrison and D. Eccleshall (*Nuclear Physics Research Laboratory, University of Liverpool*).

A multiple coincidence circuit is described which provides for amplitude discrimination of fast photomultiplier pulses. A resolving time of 20 mμs is obtainable.

The effect of humidity on the stability of inductance standards. By G. H. Rayner and L. H. Ford (*National Physical Laboratory*).

The N.P.L. sub-standard inductance coils have been found to vary in value with atmospheric humidity. The changes in inductance for a 10% increase in relative humidity range from +0·7 part in 10^4 on a 100 μH coil to −0·25 part in 10^4 on a 10,000 μH coil. The changes may be partly explained by dimensional changes in the formers of the coils.

Fundamental behaviour of sensitive springs. By Prof. R. Tomaschek (*The British Petroleum Co. Ltd.*).

It is shown that by extending a flat spiral spring by a force acting at one of its ends perpendicular or at an angle to its original winding plane, shapes of a special form, called serpent springs, can be obtained. Though capable of supporting relatively heavy loads, these springs respond under certain conditions to small changes in the loads by considerable lengthening and twisting. The conditions for obtaining such springs of high sensitivity and their fundamental behaviour are described.

LABORATORY AND WORKSHOP NOTES

A simple universal X-ray camera stand.
By M. D. Karkhanavala

A sensitive manostat.
By H. Tompa.

A simple air-lock for ionization gauges.
By C. Barrow.

A portable β-γ radiation monitor.
By B. W. Emmerson *and* S. P. Newbery.

A simple interval timer.
By M. T. Lilburne *and* D. Shipley.

A four-point probe apparatus for measuring resistivity.
By D. B. Gasson.

CORRESPONDENCE

Errors in the A.S.T.M. Index of X-ray powder diffraction patterns.
From J. W. Hughes, Isabel E. Lewis *and* A. J. C. Wilson.

British Journal of Applied Physics: Volume 7, No. 2

SPECIAL ARTICLE

The United Kingdom Atomic Energy Authority and its functions.* By Sir John Cockcroft, K.C.B., C.B.E., F.Inst.P., F.R.S. (*Atomic Energy Research Establishment, Harwell*).

The United Kingdom Atomic Energy Authority has three main groups : research, industrial and weapons. The Research Group carries out research and development directly relating to civilian application of atomic energy. The Industrial Group designs and operates factories for the production of uranium metal and the fissile materials uranium 235 and plutonium. It has also a design office for the design of pioneering type of nuclear power stations. The Industrial Group has also a Research and Development Branch which carries out experimental research into the operational problems of the factories and into specific development problems of new plant and nuclear power stations.

The nuclear power programme of the future requires the development of new types of power stations as successors to the gas-cooled graphite-moderated power stations which are now to be constructed by industry in successively improved marks. The Research and Industrial Groups together explore the different possible types of future power stations and are carrying out design studies on the most promising types. During the last year, for example, a design study on the pressurized-water reactor has been carried out in

* Published also in the *Journal* of the *B.N.E.C.*

collaboration with industry and the Central Electricity Authority (C.E.A.). The comparative merits of this and other possible Stage-2 reactors are now being assessed.

At the same time longer-range work is carried out on still more advanced reactors such as the homogeneous reactor and the fast reactor. This work combines with zero-energy reactor physics studies and is followed by construction of an experimental reactor.

Each new reactor requires the development of specific technologies, particularly in the development of appropriate fuel elements and associated chemical-processing facilities for spent fuel elements. This development requires an intensive testing programme of reactor components, particularly fuel elements, and the Authority is now building three heavy-water research and fuel-element-testing reactors to speed up such testing. These reactors require associated heavily shielded and remote-handling facilities for examining the highly radioactive components. These expensive central facilities are likely to continue to be provided by the Authority. Also it seems likely that fuel-element fabrication and chemical-processing facilities will be held by the Authority. Industry will take an increasing share of the research and development work and construction work, for reactors and nuclear power stations, and the pattern of co-operation is being worked out by experience.

The Research Group is responsible for the production and application of radioactive isotopes and radiation. These applications are growing rapidly, at a rate of about 25% a year, and it is expected soon to have very powerful sources of radiation available for industrial processes.

The research Group also looks to the future and carries out Research and long-term projects of importance to future developments.

Papers

The laminar flow of streams of suspended particles. By T. V. Starkey, F.Inst.P. (*The Technical College of Monmouthshire, Crumlin*).

It was shown theoretically in a previous paper that during the laminar flow of a suspension through a tube, and for least action, a suspended particle would follow a path adjacent to the tube axis. In general, therefore, a particle entering a tube non-axially would be expected to move with a component of translation normal to the streamlines and directed towards the axis. In the pr ..t paper this theory is developed and leads to the conclusion that for a particle at any given point in the tube this component increases with particle size. Experiments are described in which streams of coloured particles of mixed sizes suspended in water were admitted at a given point on the horizontal diameter of a tube placed horizontally, through which a steady flow of water was maintained. These coloured streams diverged on entry to the water and formed filaments in a horizontal plane. A study of the lateral movement of these filaments relative to one another, as the point of their admission to the tube and the rate of flow of water in the tube are varied, leads to the conclusion that lateral forces act on the suspended particles. Such forces, the magnitudes of which increase with particle size and with mean shear gradient, result from the motion of the particles in non-uniform velocity gradients. The motions observed lead directly to a simple flow mechanism, independent of particle configuration and orientation, which is shown to be qualitatively consistent with a number of well-established phenomena.

The inductance of two elliptic tubes. By E. E. Jones (*University of Nottingham*).

The magnetic field of two conducting tubes of non-magnetic material is determined in terms of certain vector potential components. Each tube forms the annulus between two successive elliptic cylinders of the same confocal system, and equal and opposite steady currents flow along them. The inductance of the system is determined in terms of its geometry and some numerical results are recorded.

A photographic method of obtaining stress trajectories. By A. R. Morris (*National Physical Laboratory, South African Council for Scientific and Industrial Research, Pretoria, South Africa*).

A method of superimposing a set of photographs of isoclinics is described. With each isoclinic photograph is included a grid, the lines of which are inclined at an angle corresponding to that isoclinic parameter. These grid lines, being everywhere tangential to the principal stress directions, enable the stress trajectories to be easily and accurately drawn.

A modified replica technique and its application to the examination of etched single crystals of barium titanate. By D. S. Campbell and D. J. Stirland (*The Plessey Co. Ltd., Caswell, Towcester*).

A replica technique, combining the pre-shadowing and extraction methods, has been developed and applied to the study of etched surfaces of barium titanate single crystals. The results obtained are discussed in relationship to the structure of barium titanate.

Collodion replicas from cross-sections of thin metallic strip and coatings. By D. J. Evans, A.Inst.P. (*Department of Metallurgy, University College of Swansea*).

The use of collodion as a replica material for obtaining electron micrographs of cross-sections of thin metallic strip and coatings is outlined.

A comparison of dry stripped, unbacked collodion and Formvar replicas.

By D. J. Evans, A.Inst.P. (*Department of Metallurgy, University College of Swansea*).

Dry stripped and unbacked Formvar and collodion replicas from identical areas of metallic specimens are compared, and differences other than comparative stability in the electron beam are apparent. The ease and rapidity of preparation of the collodion and also its increased resolution over Formvar commends its use for routine metallographic examinations.

The measurement, by nuclear resonance, of light water concentration in mixtures of light and heavy water.

By A. M. J. Mitchell, A.Inst.P., and G. Phillips (*Signals Research and Development Establishment, Christchurch, Hants.*).

Nuclear resonance absorption is induced in protons contained in mixtures of light and heavy water. The magnitude of the power absorption is used as a measure of the concentration of light water present and samples of known concentration are used to standardize the absorption.

Two techniques for inducing the absorption are described, one appropriate for H_2O concentrations in the range 7-100% and the other for low concentrations. In both cases the signal output from the equipment rises almost linearly with H_2O concentration. Using the first method, a signal-to-noise voltage ratio of twenty is obtained with a 7% concentration. A similar ratio is obtained from samples with 0·2% H_2O by using the second technique. The effect of flowing low concentration samples through the apparatus has been studied. The signal output falls with flow rate and at 40 ml./s is half that obtained at zero flow. Suggestions are made for improving the stability of the equipment and for reaching a quantitative theoretical understanding of the absorption signal shapes observed.

The thermal and electrical conductivities of deposited carbon.

By A. R. G. Brown and W. Watt (*Royal Aircraft Establishment, Farnborough, Hants.* R. W. Powell, F.Inst.P. and R. P. Tye (*National Physical Laboratory, Teddington, Middlesex*).

Details are given of a method used to deposit carbon from hydrocarbons at high temperatures for the production of small tubular specimens. The density had been found to vary systematically with the temperature of deposition, and the present work relates to measurements of thermal conductivity and electrical resistivity made over the range 20 to 200°C on commercial graphite and deposited carbons formed at temperatures of 1,800, 1,900, 2,000 and 2,100°C. The thermal conductivities of the specimens deposited at 2,000 and 2,100°C were found to be exceptionally high. At 50°C the value for material deposited at 2,000°C was approximately 20% greater than that of copper ; for material deposited at 2,100°C it was approximately 40% greater than that of copper. These measurements were made in a direction parallel to the axis of the tube for which direction the deposited carbon showed a pronounced layered structure. This, and an associated high electrical resistance normal to its plane, made it difficult to determine the electrical resistivity of the sample deposited at 2,100°C The high thermal conductivity appears to result from the high lattice conductivity of this material, the electronic component being only of the order of 1%.

Stress distribution in a tee junction of thick pipes.

By H. Fessler and B. H. Lewin (*Department of Mechanical Engineering, University of Nottingham*).

The stress distribution on the inner surfaces of both pipes near their juncture, as caused by internal pressure, was determined by the "frozen stress" photoelastic technique. An approximate method of calculation (based on the theoretical solution for a hole in an infinite plate under uniform tension) was developed and a measure of agreement between the calculated and measured stresses was found.

Correspondence

Errors in the A.S.T.M. Index of X-ray powder diffraction patterns.

From J. W. Hughes, Isabel E. Lewis *and* A. J. C. Wilson.